The Anthrax Terror

DOD's Number-One Biological Threat

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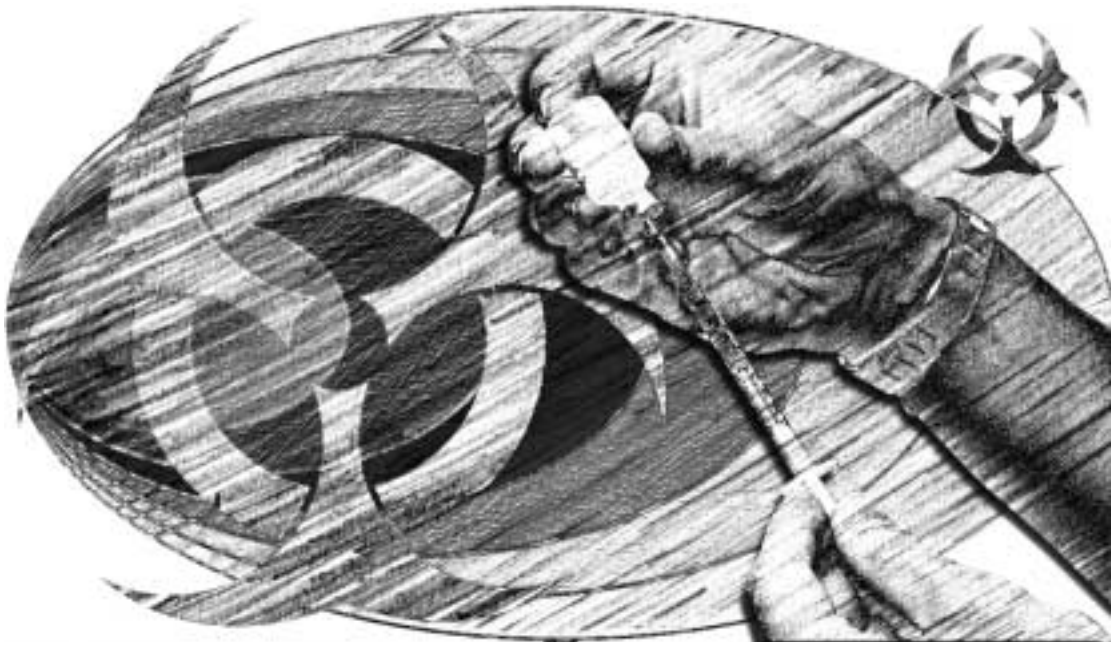

Editorial Abstract: The chance that our armed forces will encounter biological weapons has increased dramatically since the dissolution of the USSR. Drs. Johnson-Winegar and Davis give us an in-depth tutorial on anthrax, the predominant bioweapon threat, and they provide clear rationale for our needing a viable vaccination defense.

TODAY THE US military faces a variety of threats around the world, ranging from nuclear ballistic missiles to information warfare. The ability to conduct biological warfare (BW)—to employ biological agents like anthrax as weapons—lies within our adversaries' threat arsenals. This increasingly discussed threat is not as readily appreciated and understood as kinetic-energy threats but presents no less and perhaps an even more daunting challenge to the Department of Defense (DOD) and the nation. The sobering reality is that this threat impacts our national security, and

its effects could dramatically change our society.

The relative ease with which biological weapons can be obtained, along with other changes in the world, sets the stage for a different type of warfare in the twenty-first century. BW may reshape the way nations fight wars. If used on a massive scale against the civilian populace, BW could redraw the patterns of our society as people become increasingly concerned about being victims of this silent and deadly mode of warfare. Scientists predict the next several decades will pose challenges as current BW technology evolves into futurist biological weapons such as binary BW agents, stealth viruses, and malicious designer genes. In fact, biological warfare capabilities are probably where nuclear weapons were in the 1940s.[1]

Underscoring how seriously the US military views biological weapons in general and anthrax in particular, the Joint Chiefs of Staff in 1996 declared anthrax the number-one biological-weapon threat to our military forces.[2] Why is DOD so concerned about biological warfare and particularly anthrax? What can be done to mitigate this threat? Knowing that all vaccines have potential risks, is DOD justified in having a goal of vaccinating one hundred percent of the military against anthrax, or should alternative solutions be adopted?

Why the Concern about Biological Warfare?

Millions of defense dollars are currently funding projects to protect our military forces and nation against potential BW attacks. During the last 75 years, several international treaties and arms control agreements have been put into place, yet the number of nations with BW programs has not seemed to wane.[3] Based on the incidence of past use of BW in the twentieth century, globalization, technology transfers, and an increasing interest in BW, our military forces should expect and be prepared to encounter and cope with BW use during the twenty-first century. The world is changing, and these changes are escalating the BW risk. Today, rogue states and some terrorist groups are able to overcome technological barriers more easily due to the increased flow of information and access to technologies that were heretofore unavailable. Along with nuclear and chemical arms, biological weapons are part of an unholy trinity of weapons of mass destruction (WMD). Although chemical warfare (CW) and BW programs require different equipment and expertise, they do have several common features. Both are considered inexpensive weapons that can inflict massive casualties, and both are usually most effective when inhaled. If given advance warning, military personnel can don protective masks and suits that will protect them from both chemical and biological weapons. Neither type of threat destroys property like conventional or nuclear weapons. As a result of these and other factors, countries that have CW programs usually have BW programs. Similarly, countries with BW programs are likely to have CW programs. Since chemicals have been used more widely as weapons, the past use of BW has often been overlooked. Yet, the historical incidence of BW (including anthrax) and the emergence of several other factors make it an increasing threat for our near and distant future.

BW Use in the Past

During the US Revolutionary War, Gen George Washington received reports that the British were spreading smallpox among colonial troops. At first Washington gave little credence to these reports until his troops began to come down with the dreaded disease.[4] At a time when smallpox was killing 16 percent of the people it infected, Washington had to make some tough decisions if he was to preserve the colonial army. His only apparent option was to order mandatory inoculation of his forces,[5] which he knew at the time would cause a mortality rate of 0.33 percent (one per 300 inoculated would die). On 6 January 1777, Washington gave the order for the colonial army to be variolated. Variolation involved the intentional inoculation of smallpox or-

ganisms into the body, a more dangerous procedure than vaccination with cowpox virus ("smallpox vaccination") developed a few years later in 1796. [6] Although data is not available on the number of deaths caused by inoculation, most of the people who underwent variolation survived and were protected from smallpox.

Biological warfare was used in World War I by the German military, who recognized the mule and the horse as important to the Allies for moving equipment. Accordingly, the Germans embarked on an antianimal BW campaign. They achieved their most notable success when they infected forty-five hundred mules and horses belonging to the Allies in Mesopotamia with glanders.[7] Additionally, the Germans are known to have set up a laboratory in a private house in Chevy Chase, Maryland, where large quantities of anthrax and glanders organisms were grown. A German agent, Capt Frederick Hinsch, used these to inoculate horses in Baltimore, Maryland. An extensive network of German agents in the United States injected horses, mules, and cattle with glanders and anthrax at the stockyards just before the animals' departure to the European theater.[8] The Germans were also accused of covert BW attacks on humans, allegedly using cholera in Italy and plague in Saint Petersburg, Russia.[9]

The Japanese Imperial Army experimented with over 16 biological agents as tools of warfare between 1932 and 1945. This took place in numerous locations in Asia, where the Japanese experimented with and employed multiple types of biological-weapon delivery systems. It is estimated that some 10,000 Chinese prisoners, US prisoners of war, and British detainees were killed by some of the most gruesome human experimentation in history.[10] The Japanese used BW agents such as anthrax, plague, tularemia, and smallpox to gauge effects and to help them understand how to weaponize such diseases. [11]

Dr. Ken Alibek, the former deputy director of Biopreparat and chief scientist of the Soviet offensive biological warfare program, defected to the United States in 1992.[12] Alibek has alleged that the Soviets employed biological warfare during World War II. In his book *Biohazard,* he states that there is evidence tularemia was used by the Soviet troops to help stop the German panzer troops in the Battle of Stalingrad. The resulting tularemia outbreak may have halted the Nazi advance, but the Soviet troops also developed the disease because of what Alibek suspects was a sudden change in wind direction. Over a hundred thousand cases of tularemia were reported in the Soviet Union in 1942, a tenfold increase in incidence experienced in 1941 and 1943. Seventy percent of the cases were the respiratory form of the disease, which is the form that would have been expected from a biological weapon rather than a natural outbreak of the disease.[13]

From 1974 to 1981, the USSR was actively using chemical/biological warfare (CBW). *The Textbook for Military Medicine*, published in 1997, states that there were 10,923 deaths from CBW use by the Soviets from aircraft spray, rockets, bombs, and other methods. Those were the result of 497 CBW attacks in Afghanistan, Laos, and Kampuchea (Cambodia).[14]

The Soviet Union developed a huge offensive BW program during the 1970s and 1980s. "Secret" cities were built as part of a communist strategy to keep a massive, clandestine program. While the US offensive BW program (1942–69) focused on BW agents that were curable, the Soviets were constantly striving to develop agents that were difficult to treat. Not wanting to repeat the incident at Stalingrad where Soviets were infected by their own weapons, they began to formulate a strategic focus—targeting deep strikes into the United States. As recently as 1988, BW agents such as anthrax, plague, smallpox, and an Ebola-like virus were earmarked for placement in SS-18 missiles pointed at major US cities. An SS-18 could carry enough anthrax to wipe out New York City.[15]

Not only are states willing to deploy such unconventional weapons, but now terrorist groups have gained an interest in them. The Aum Shinrikyo cult is best known for its nerve

(sarin) gas attack in the Tokyo subway on 20 March 1995. Fortunately, the lack of sarin purity and the Aum's poor delivery mechanisms limited the effects to 12 deaths and fifty-five hundred casualties. What is not generally well known is that the group also had manufactured biological weapons and attempted to use them. They tried to deploy anthrax on four occasions and botulinum toxin at least four other times.[16] One planned target of a botulinum toxin attack was the US naval base in Yokosuka in April 1990.[17] Fortunately, none of these attacks was successful; otherwise, the casualties could have been in the tens or even hundreds of thousands.

World Environment

The Department of State has identified seven states as sponsors of international terrorism. These state sponsors include Iran, Iraq, Syria, Libya, Cuba, Sudan, and North Korea.[18] Even more alarming, several of these states are also believed to have a biological warfare capacity.[19] The 1980s and 1990s brought an escalation in the number of nations deciding to develop their own biological-weapons program. Most conspicuous among other states often mentioned as possessing an offensive BW program are China, Russia, and Israel.[20] Russia's declining economy has also caused other international concerns as Russian scientists and workers who were previously employed in the BW program may decide to work for other countries.

The actual and potential movement of highly skilled professionals (the so-called brain drain) from the previous Russian and South African offensive BW programs is alarming.[21] At its height, the Soviet BW effort had as many as 60,000 people working on different aspects of the program.[22] A good number of those individuals have marketable skills that could be used by countries eager to develop their own program. Many of the former Soviet BW scientists are either unpaid or receive only minimal pay (about one hundred dollars per month), making relocation to another country appear lucrative.[23] Likewise, the South Africa BW program began receiving scrutiny under President F. W. de Klerk in the early 1990s, which led to the firing of numerous scientists working the program. This kind of activity only adds fuel to rogue states seeking South African scientists to assist with their countries' development of programs.[24] South Africa recently declared it no longer has an offensive BW program and that all its BW activities are related to defense.

The Internet is another source of ready information for those bent on obtaining a biological weapons capability. Heretofore, one of the greatest barriers to a full understanding of the acquisition, production, and deployment of BW has been a lack of technical knowledge. The Internet now provides a massive repository of information on BW from hundreds of sources. BW exercise scenarios used by governmental agencies on the Internet supply ideas to terrorists on how to effectively deploy BW. Books are available that describe how to obtain, grow, and deploy BW agents such as anthrax, ricin, and botulinum toxin. Other unclassified information goes into great detail discussing the benefits or shortfalls of particular BW agents.

Along with the change from a bipolar to a multipolar world and the proliferation of information through the Internet, terrorists' increased interest in biological weapons has DOD concerned.[25] The trend of terrorism might be captured in two words—*massive lethality*.[26] While the number of terrorist events was down in 1999, such events are involving larger numbers of people and more fatalities per event. Examples of this trend include the murder of 270 people aboard Pan Am Flight 103 in 1988 and the US Embassy bombings in Kenya and Tanzania where 224 people were blown up in 1998.[27] Additionally disturbing in the terrorism trends is the evolution toward transnational groups.[28] The Osama bin Laden or the Aum Shinrikyo organizations serve as operative examples. They have or have had a massive international network capable of exporting terrorists around the globe in pursuit of their political objectives.

What Is Anthrax?

Anthrax is one of the oldest recorded diseases known to man. The disease is endemic to wild and domestic animals, primarily herbivores such as cattle, horses, and sheep, but it also infects other animals including cats, monkeys, and humans. Naturally occurring anthrax in humans is a disease acquired by contact with infected animals or contaminated animal products such as hides, and it generally manifests itself as cutaneous lesions. It is thought that the fifth and sixth plagues the Egyptians suffered in approximately 2000 B.C. were due to an anthrax infection. During the Middle Ages, the disease, called Black Bane, ravaged the European countryside, killing scores of cattle and sheep.[29] Inhalational anthrax is a new form of the disease that emerged in the industrial age due to aerosolized particles in wool mills.

In 1876, Robert Koch definitively proved that *Bacillus anthracis* was the causative agent for disease. His development of "Koch's postulates" through experimentation with anthrax provided medical practitioners and scientists with a method to prove that a specific bacterium caused a specific disease.[30] *Bacillus anthracis* was not only the first bacteria to be proven to cause a disease, it was also the first bacteria (as opposed to a virus) against which a vaccine was developed.[31] In 1796, Edward Jenner created the first vaccine for a virus, smallpox, but it was nearly one hundred years later before the first vaccine against a bacterium was developed.[32] In 1881, Louis Pasteur created the first bacterial vaccine against *Bacillus anthracis*.[33]

Although the United States experienced approximately 130 cases of anthrax each year in the early 1900s, this has been reduced to about one case per decade since the 1970s.[34] While rare cases of cutaneous anthrax are reported in the United States, no case of inhalational anthrax has been reported in the United States since 1978.[35] Much of the decrease is probably due to vigorous livestock vaccination programs in endemic areas and human vaccination of high-risk individuals.[36] The largest human epidemic occurred in Zimbabwe in 1978–80, resulting in more than six thousand cases, of which almost all were the cutaneous form.[37]

Anthrax infection in humans comes in three forms: cutaneous, gastrointestinal, and inhalational.[38] These forms of the disease also describe how a person is exposed to the *Bacillus anthracis* spore. Hemorrhagic meningitis can be a secondary condition in any of these forms of the disease if the disease progresses to bacteriemia.[39] The cutaneous form of the disease is the most common form, making up 95 percent of all occurrences.[40] Without treatment, one in five people would die from cutaneous anthrax. With treatment, virtually a hundred percent survive.[41] The gastrointestinal form of the disease is much more severe and may result in a fatality rate of 50 to one hundred percent of untreated persons.

Inhalational anthrax is the form most likely to be seen in a BW attack, and it approaches a 100 percent fatality rate if treatment is not administered almost immediately.[42] If treatment begins 48 hours after symptoms from inhalational anthrax, the mortality rate can still be as high as 95 percent.[43]

An incubation period (without symptoms) would range from one to six days.[44] Individuals would initially manifest nondiscrete flulike symptoms (e.g., fever, headache, muscle ache, etc.). This period may last 24 to 72 hours, followed by a few hours of "improvement." The terminal stage is an almost precipitous decline resulting in death within hours.[45] None of the available treatments can slow the incidence of mortality significantly once the initial symptoms appear.

Bacillus anthracis is a large, Gram-positive bacterium found in many soils around the world and can survive in spore form for decades. There have been cases where the spores have been found still alive after two hundred years.[46] Although some strains have a greater virulence than others, they all must have certain characteristics to cause disease.

In its vegetative (growing) form, the bacillus has a protective capsule that keeps a human's

immune system from killing it.[47] Disease-causing strains of anthrax bacteria are characterized by three protein components that they produce.[48] These three components (protective antigen, lethal factor, and edema factor) combine to produce the two deadly toxins (edema toxin and lethal toxin) that cause damage to the human body.[49] In experimental animal studies, once toxin levels reach a critical threshold, death occurs even if antibiotics are used to eliminate the bacteria.

Thirty-three different strains of disease-producing *Bacillus anthracis* have been tested in guinea pigs, seven strains in rabbits, and four strains in rhesus monkeys; all testing in these animals confirms that the same toxins produce disease in animals as well as man.[50] In laboratories *Bacillus anthracis* can be grown in such a way that the protective antigen can be isolated. This technique has helped scientists to develop the current Food and Drug Administration (FDA)-approved vaccine that utilizes this key disease-mediating protein (protective antigen) to develop antibodies to prevent the disease.

Is DOD Justified in Labeling Anthrax as the Number-One Biological Threat?

Millions of dollars from the DOD budget are currently being spent to mitigate the potential effects of biological weapons. Since anthrax is number one on the list, it receives a large share of the counter-BW budget dollars. If DOD is focusing on the number-two threat, rather than on what is the most likely BW-agent threat to our nation and military, we could be extremely vulnerable. Several factors support DOD's decision to focus on anthrax, including the intermittent use of anthrax in the twentieth century, the unique benefits of *Bacillus anthracis* as a BW agent, and the proliferation of BW programs worldwide with anthrax as their core biological agent.

Anthrax: The Biological Weapon of the Twentieth Century

During the first half of the twentieth century, there have been a number of attempts at using anthrax as a weapon. Besides the previously mentioned uses of anthrax by the Germans in World War I and by the Japanese from 1932 to 1945, other countries saw value in having anthrax as an offensive weapon. During World War II, the United States and Britain started their offensive biological warfare programs, and both came to recognize *Bacillus anthracis* as one of several primary biological agents for possible warfare use. There is no record of any US or British use of biological weapons, but work was done to attempt to weaponize a variety of BW agents.

In 1969, President Richard M. Nixon made an international announcement that the United States would unilaterally disband its offensive BW programs and destroy all its BW weapons.[51] Additionally, in 1972 other nations joined with the United States and the USSR in signing the Biological Weapons Convention (BWC), which prohibited the research, production, or use of BW. All was well until the Sverdlovsk Anthrax Incident.

On 2 April 1979, an accident involving *Bacillus anthracis* occurred at a secret biological-weapons facility in the town of Sverdlovsk (now Yekaterinburg) in the USSR.[52] Unlike the Chernobyl nuclear meltdown where the accident could be seen and heard for miles, this accident happened silently in the early hours of the morning when an employee did not properly replace a filter on an exhaust vent. As a result, between 64 and 104 people died from anthrax infection.[53] The cover story was that these people died from infected meat. The USSR denied it was a BW accident until 13 years later when Boris Yeltsin admitted the infection came from the escape of anthrax from a BW production facility, confirming the fact that the USSR had been in direct violation of the BWC. The Communist official in charge of the cover-up in 1979 was none other than Boris Yeltsin. The US biological program had only

two recorded cases of accidental anthrax infections (1951 and 1958), and both were fatal.[54]

Although Saddam Hussein was ready to use anthrax in the 1991 Gulf War,[55] his lack of use might lead some to believe the anthrax threat was exaggerated. One study done by the Office of the Secretary of Defense (OSD) modeled the scenario of Iraq's using its weaponized anthrax by spraying it from one of Saddam's dedicated F-1 Mirage aircraft equipped with spray tanks. In ideal weather conditions, an estimated 76,300 deaths would have been suffered by US forces within the first few days of the Desert Storm ground campaign. This would have devastated our forces by killing 24 percent of the 320,000 US soldiers in the region. However, if they had all been vaccinated, only 122 deaths might have resulted.[56]

After the nerve gas attack in Tokyo in 1995, extensive investigations revealed that Aum Shinrikyo had acquired, produced, and weaponized *Bacillus anthracis*. On four repeated occasions (1990–95), the cult tried to spray the bacterial agent over Tokyo.[57] Fortunately, they were not successful in inflicting mass casualties. A few deaths could have been caused by their anthrax release and would probably have never been discovered due to the large number of unexplained deaths that routinely occur in large cities. These attacks failed due to the cult's lack of technological understanding of anthrax as a BW agent. If Aum Shinrikyo had developed and disseminated an anthrax spore similar to the one released at the Sverdlovsk accident, there could have been many thousands of deaths. In other words, Tokyo escaped a BW catastrophe.

The Benefits of Employing Most Biological Agents

Biological weapons offer an opportunity for the less powerful nation to "level the playing field" against the world's military superpower or for a terrorist group to incite a public reaction of enormous magnitude. How can this be? Five key attributes underlie the attractiveness of all biological weapons.

First, biological weapons are inexpensive to produce compared to other weapons of mass destruction.[58] These weapons are often referred to as the "poor man's nuke." With only a few hundred dollars to purchase fermentation equipment for "home brewing," many people could grow large amounts of viable bacteria in a few days. With a few thousand dollars, one would have sufficient funds to acquire, produce, and deploy bacterial agents that could kill thousands of people. It has been calculated that to get the same lethal effect from a nuclear weapon, you would have to invest eight hundred dollars for every dollar invested in a BW program.[59]

Second, dual-use equipment gives a BW perpetrator the ability to produce either legal vaccines/pharmaceuticals or BW agents.[60] Since the same equipment is required for legal uses, the perpetrator can easily deny that the equipment was used for production of biological weapons.[61] This also helps to lower the overall cost of the biological-weapon production if the facility also can be involved in a legal activity that produces consumer products. Dual-use capability also means a staff of trained personnel is always available for production.

Third, bullets are fast, bombs are loud, and their effects often dramatically evident, but BW silently inflicts its damage. The victim would likely be unaware an attack was taking place. Imagine being able to deliver a tasteless, odorless, and colorless weapon that could kill your enemy. [62] These attributes allow an adversary to disseminate these infectious agents without being noticed. The victim might have to take only one good breath of this invisible cloud, and his fate would be sealed.[63] This leads to the fourth attribute, plausible deniability. A state or a terrorist group can deny that it delivered a BW attack. Short of DNA sequencing of the agent used in the attack and matching it with an agent in the perpetrator's possession, proof of the attack may be speculative at best and, even then, sequencing may not provide conclusive

evidence of culpability.

Finally, most military weapons act immediately to get the desired effect, but the delayed effect (incubation period) from BW could work to an enemy's advantage. Various BW agents have incubation periods that range from one to 60 days. Imagine an adversary who knew he could not mass troops on a border because satellites would pick up his movements and US forces might respond to the threat. In the case of anthrax, the adversary could wait to move troops until 72 hours later when most people were either dead or starting to show symptoms. The US forces would be in a "survival mode" trying to save every soldier, which could impede the US ability to respond with an appropriate military response.

Specific Benefits of Using Anthrax as a BW Agent

Although most of the attributes of *Bacillus anthracis* discussed below are not unique to anthrax, it is the only biological agent that has *every* attribute. While some attributes, such as lethality, are seen as positive for *Bacillus anthracis*, it may actually be negative to a perpetrator that prefers a nonlethal agent. Nevertheless, the following is a list of the agent's attributes that contribute to DOD's decision to designate anthrax as the number-one biological threat to the military.

- *Highly lethal* - Virtually 100 percent of exposed personnel will die from one breath of air with a lethal concentration of anthrax spores.[64] A lethal concentration has been estimated to be eight thousand spores to 50,000 spores.[65]
- *Noncontagious*[66] - This allows a military to use it against another military without concern of secondary spread from person to person. It also allows anthrax to be targeted at specific populations. Both of these features are particularly attractive to certain tactical, operational, or strategic applications. Smallpox and pneumonic plague (*Yersinia pestis*) are often high on the list of BW agents, yet these are both communicable and thus much more difficult for operational or tactical applications and also more dangerous to work with.
- *Easy to protect with advance preparation*[67] - An enemy could vaccinate his troops prior to an attack and know they were protected. Likewise antibiotics can be given in advance to mitigate the effects. This would add an enormous advantage physically and psychologically for invading forces to know that they were protected when entering a contaminated zone.
- *Stores well for long periods* - Anthrax spores can remain viable for years.[68] Climate control is not as critical as with other microbes because the spores have been known to live for decades in arduous environments. Anthrax was tested in the 1940s on Gruinard Island off the coast of Scotland, and viable spores could still be found until it was decontaminated in 1986.[69]
- *Stable in multiple weapon systems* - Many biological agents cannot withstand the turbulence experienced from being sprayed or detonated over a target. Yet the hardiness of anthrax allows enough of it to survive to retain its lethality. This versatility lowers the complexity for a BW perpetrator because one agent can be used in a missile warhead, artillery or mortar shell, or can be disseminated by a sprayer.
- *UV resistant*[70] - Sunlight (ultraviolet rays) will cause all potential BW agents to degrade. BW agents like tularemia die rapidly when exposed to sunlight. Only two agents, *Bacillus anthracis* and *Coxiella burnetii*, are considered resistant to degradation from sunlight.
- *Short incubation period* - If a weapon were to be used against military forces, being able to predict its time of effect is important. Since the incubation period

(lag time between the attack and the first symptoms) of anthrax is one to six days, prediction of the timing of the effect would be much easier than for an agent such as brucellosis that has an incubation period ranging from five to sixty days.

- *Easily available* - Since anthrax is an animal disease that occurs around the world, soil samples from many different locations make anthrax readily available at numerous locations around the globe. Additionally, there are approximately fifteen hundred microbiologic repositories internationally that sell cultures worldwide to laboratories, vaccine companies, and other entities presumably for diagnostic and treatment purposes. These distribution centers serve as a potential source for anthrax procurement.[71]
- *Easy to produce* - Unlike viral agents that require more complicated production equipment, *Bacillus anthracis* can be produced in equipment common to almost any biologic production. It is easier to produce than almost any other BW agent.[72]
- *Naturally occurs at one to five microns*[73] - This is the optimal size for a BW agent because it is the right particle size to be breathed in and to get to the bottom sacs (alveoli) in the lungs. One of the more difficult aspects of developing a BW agent is to get it small enough so that it can get into the alveoli but large enough to stick to the wall of the alveoli and not be blown back out the airways. *Bacillus anthracis* is no exception. Although the spores naturally occur at the proper size, special milling is required to keep the spores from clumping into larger particles.
- *Can be used as a powder or liquid* - This flexibility allows anthrax to be used in various delivery systems, thereby enhancing a perpetrator's options.[74]
- *Requires a small amount for a mass effect* - The Office of Technology Assessment for the US Congress estimated that 64 pounds of anthrax delivered from an aircraft as an aerosol line in an area like Washington, D.C., would result in up to three million casualties with ideal weather conditions.[75] Another assessment by Oak Ridge National Laboratories showed that to produce the same lethal effect on a square-mile area, a perpetrator would need 1,763 pounds of nerve gas (sarin), 0.2 pounds of botulinum toxin (Type A), or only 0.02 pounds of anthrax spores.[76]

Who Has an Anthrax BW Offensive Program?

The open literature is filled with charts and reports indicating who has BW programs and who has suspected programs.[77] It is very difficult to judge how extensive the BW threat might be since such capability could well be within range of most countries and biotech/pharmaceutical corporations and groups. Intuitively, one would think that any country that has an offensive BW program would probably have anthrax as a key component of its program. Consider the former Soviet Union, the United States, the Aum Shinrikyo, Iraq, and others.[78] Anthrax was one of the agents at the top of their list for production and weaponization. Likewise, many countries currently have weaponized anthrax, and many others are trying to acquire it.[79] Table 1, compiled by renowned biological terrorism expert Dr. Seth Carus, provides an idea of reported BW programs from different sources.

Any country listed on the table that has even a suspected BW program has probably thought about anthrax as a biological weapon. DOD recently responded in an unclassified document that "more than seven countries including Iraq, Iran, Syria, and Russia have or are suspected of developing this biological warfare capability."[81] Israel, Taiwan, and Libya are also suspected of having the in-

Table 1

BW Programs by Country and Sources of Information

Country	ACDA* 1995–97	DOD* 1996–98	FIS* 1993	DOD 1988–90	Open Sources Pre-1993
Bulgaria					X
China	X	X		X	X
Cuba		X			X
Egypt	X		X		X
India			X		
Iran	X	X	X	X	X
Iraq	X	X	X	X	X
Israel			X		X
Laos					X
Libya	X	X	X	X	X
North Korea		X	X	X	X
Russia/Soviet Union	X	X		X	X
South Africa					X
Syria	X	X		X	X
Taiwan	X			X	X
Vietnam					X

*ACDA = Arms Control and Disarmament Agency
DOD = Department of Defense
FIS = Foreign Intelligence Service of the Russian Federation

Source: W. Seth Carus, "Biological Warfare Threats in Perspective," *Critical Issues in Microbiology* 24, no. 3 (1998): 154.

frastructure prepared to grow and weaponize anthrax.

Secretary of the Air Force F. Whitten Peters told the Senate Armed Services Committee on 21 July 1999 that "[anthrax] has been weaponized and we know it is deployed in about 10 countries around the world."[82] Others have stated that there are at least 17 nations with BW programs. Three countries—the USSR, Iraq, and South Africa—had BW programs of which anthrax was an important part during the last 20 years. Their large, covert BW programs sent a strong signal to the international community.[83] The message is that a state can have an active BW program, sometimes of gargantuan size, which can be relatively hidden from the intelligence community.

Ken Alibek reports that the USSR's intricate BW enterprise produced tons of BW agents including anthrax, plague, tularemia, smallpox, and the Marburg virus. During the 1980s, some of the Soviet Union's intercontinental ballistic missiles (ICBM) reportedly were loaded with "cocktails" of these agents and targeted at major US cities such as New York, Chicago, Los Angeles, and Washington, D.C. Alibek states that one ICBM could carry enough anthrax to wipe out the population of New York City. Many of his revelations about the magnitude of the Soviet BW program have

been corroborated by other credible sources such as Jonathan B. Tucker, director of the Chemical and Biological Weapons Nonproliferation Project at the Center for Non-Proliferation Studies in Monterey, California.[84]

Likewise, Saddam Hussein's BW program seemed to slip by the awareness of US intelligence.[85] Everyone was aware that Iraq had CW because of its documented use of nerve/mustard agents in the Iran-Iraq War and Iraq's use of cyanide/nerve agents on its own citizens, the Kurds. The United States and others also suspected that Iraq had a BW program, which was confirmed in 1991/92 by the UN Special Commission (UNSCOM) inspections. It wasn't until the 1995 defection of Lt Gen Hussein Kamal, Saddam's son-in-law and the former head of the Iraqi BW program, that the real magnitude of its program came to light. The information he shared with Rolf Ekéus, executive chairman of UNSCOM, revealed that the Iraqis had a much larger program than UNSCOM realized and that it was organized around anthrax and botulinum toxin. Iraq indeed had large stores of weaponizable anthrax and many weapons loaded with anthrax (bombs, Scuds, Al Hussayn warheads, 122 mm rockets, artillery shells, spray tanks for fighters and remotely piloted aircraft).[86] Iraq had been able to hide much of its BW program in spite of the intrusive UNSCOM inspections.[87]

South Africa's previous BW program still seems to be a bit obscure. Investigation into alleged atrocities was initiated in the early 1990s. There are claims that Rhodesian troops were provided anthrax in the late 1970s to be used against guerilla rebels trying to overthrow the white minority rule.[88] Dr. Wouter Basson, a former special forces army general and physician to former president P. W. Botha, headed the South Africa BW program. Basson is still working for South Africa in its military's medical section.[89]

Is Vaccination the Right Decision?

Again, an aerosol exposure to anthrax spores causes respiratory anthrax, which is rapidly fatal in nearly 100 percent of cases if untreated. Given the rarity of the disease and its quick progression, a diagnosis of inhalational anthrax is difficult to make. Treatment consists of massive doses of antibiotics and supportive care. However, there are no human studies available on postexposure treatment. Limited studies in monkeys have shown that postexposure treatment with antibiotic (ciprofloxacin or doxycycline) plus administration of vaccine is effective in preventing death.[90] Given the potential for an unrecognized weapon release, it makes sense to provide protection to our military personnel with an effective vaccine before exposure.

The US vaccine known as Anthrax Vaccine Adsorbed (AVA) is an inactivated cell-free product and has been licensed by the Food and Drug Administration since 1970. The bacteria's toxin components are the primary factors in disease. Since the toxin plays such a critical role in the pathogenesis of anthrax, it was a logical step to develop a vaccine based on toxin components. The protective antigen (PA), a constituent of lethal and edema toxin, is the primary component of the currently licensed anthrax vaccine. The filtrate of the cultures of an attenuated strain is adsorbed to aluminum hydroxide to increase antibody responses, and preservatives are added for stability. The Michigan Department of Public Health (MDPH) held the license and produced modest quantities of vaccine as needed between 1970 and 1990. Primary customers included at-risk veterinarians, wool-mill workers, and laboratory workers who handled anthrax cultures or potentially contaminated materials.

At the time of Operation Desert Shield/Desert Storm, the MDPH had a limited production capacity. Due to DOD's critical need for large quantities of vaccine, the MDPH immediately began to produce as much vaccine as possible in the existing facility. Since specialized equipment (such as 100-liter fermenter tanks) was essential, DOD authorized purchase of additional tanks to set up three identical production lines. The MDPH produced all the AVA that was used for US forces

in Desert Shield/Desert Storm. A total of approximately 150,000 individuals received one or more doses of anthrax vaccine, approximately 250,000 doses in all.

The vaccine is licensed to be given in a six-dose series, with the first three doses given at two-week intervals. Doses four, five, and six are given at five- or six-month intervals. The perfectly administered series is referred to as zero, two, and four weeks, six, 12, and 18 months. Thereafter, annual booster doses are required to maintain immunity. The vaccine was licensed on the basis of a study conducted in wool-mill workers showing that AVA was effective in reducing the number of cases—the cutaneous and inhalational forms jointly—of anthrax infection.[91]

Since it is unethical to expose humans to biological-warfare agents, most of the information available on the efficacy of the vaccine against inhalational anthrax is derived from animal data. Studies have been conducted in mice, guinea pigs, rabbits, and nonhuman primates using the aerosol route of exposure.[92] Rabbits and rhesus monkeys have been found to be the animal model most like humans in terms of disease pathology and antibody response. In one series of experiments using experimental monkeys, inoculation with two doses of this vaccine completely protected all the animals against an aerosol challenge given at eight or 38 weeks after vaccination.[93] In all, 62 of 65 vaccinated monkeys and 114 of 117 vaccinated rabbits survived lethal challenge, whereas all unvaccinated control animals died.[94]

When the state of Michigan decided to divest its vaccine production capability, Bioport Corporation bought the MDPH facilities in September 1998. Bioport has renovated the facilities and has submitted a Biological License Application supplement to meet standards set by the FDA. At the time of this writing, there is no approved current new production of vaccine, and DOD is using vaccine from the existing stockpile. All doses administered to US forces have passed potency tests and tests for sterility, purity, and safety.

In two different studies, the incidence of significant local and systemic reactions to the vaccine in the placebo-controlled field trial was 2.4 to 2.8 percent and 0.2 to 1.3 percent.[95] Local reactions consist of induration, erythema, edema, warmth, and tenderness at the injection site. These reactions peak at one to two days and usually disappear within several days. Systemic reactions may include myalgia, headache, and moderate malaise that may last for a few days. These types of reactions have been seen with many other routinely administered vaccines and present no cause for concern.

The secretary of defense announced in December 1997 a plan to immunize all active and reserve military personnel with the AVA. The secretary stipulated that immunizations would not begin until DOD (1) established a means of testing the vaccine over and above tests required by the FDA, (2) developed a system for tracking vaccinations, (3) approved operational and communication plans for the vaccination program, and (4) had an outside expert review the health and medical aspects of the program. In May 1998, the secretary announced that all these conditions had been met, and in August 1998, DOD began the Anthrax Vaccine Immunization Program. To date, over 1.8 million doses of vaccine have been administered to more than 488,000 people.

Conclusion

The anthrax threat to the US armed forces is real. Evidence continues to mount that more states and nongovernmental organizations unfriendly to the United States either have or are building BW programs. The lethality, hardiness, and ease of production of the anthrax bacteria have made it a mainstay of known BW programs. These same qualities make producing and weaponizing anthrax a top priority for many developing countries and nonstate actors trying to boost their influence on the global stage. The chance of US forces encountering anthrax is greatly enhanced by multiple deployments to high-risk

regions of the world. These factors, combined with a near 100 percent postinfection mortality rate, make it strategically and morally necessary for DOD to do whatever it can to defend its forces against this potentially devastating weapon.

The only defense against an anthrax attack, other than destroying the weapons before an attack and making use of personal protection during an attack, is to vaccinate service members. The vaccine currently being administered to the US armed forces has been used safely for 30 years and has passed extensive testing by the FDA. As with most commonly used vaccines, uncomfortable reactions to anthrax vaccinations do occur in a small percentage of cases. These reactions present little cause for concern and pale compared to the effectiveness of the vaccine against a virtually untreatable and fatal disease. The data is convincing and clear that the protection provided by the anthrax vaccine makes it the appropriate choice for protection of US forces against this biological-warfare agent. □

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